

**North Aleutian Basin Play 6: Mesozoic Buried Granitic Hills (Jurassic-Cretaceous Magmatic Rocks)**

**Geological Assessment**

*GRASP UAI: AAAAA HAG*

*Play Area: 46,810 square miles*

*Play Water Depth Range: 15-400 feet*

*Play Depth Range: 6,000-12,000 feet*

*Play Exploration Chance: 0.04095*

<b>Play 6, Mesozoic Buried Granitic Hills (Jurassic-Cretaceous Magmatic Rocks), North Aleutian Basin OCS Planning Area, 2006 Assessment, Undiscovered Technically-Recoverable Oil &amp; Gas</b>			
Assessment Results as of November 2005			
<b>Resource Commodity (Units)</b>	<b>Resources *</b>		
	<b>F95</b>	<b>Mean</b>	<b>F05</b>
BOE (Mmboe)	0	67	330
Total Gas (Tcfg)	0.000	0.206	1.169
Total Liquids (Mmbo)	0	30	122
Free Gas** (Tcfg)	0.000	0.195	1.128
Solution Gas (Tcfg)	0.000	0.010	0.041
Oil (Mmbo)	0	26	93
Condensate (Mmbc)	0	5	29

\* Risked, Technically-Recoverable  
 \*\* Free Gas Includes Gas Cap and Non-Associated Gas  
 F95 = 95% chance that resources will equal or exceed the given quantity  
 F05 = 5% chance that resources will equal or exceed the given quantity  
 BOE = total hydrocarbon energy, expressed in barrels-of-oil-equivalent, where 1 barrel of oil = 5,620 cubic feet of natural gas  
 Mmb = millions of barrels  
 Tcf = trillions of cubic feet

**Table 1**

Play 6, the “Mesozoic Buried Granitic Hill” play, is a subordinate play in the North Aleutian Basin OCS Planning Area, with 3% (67 Mmboe) of the Planning Area energy endowment (2,287 Mmboe). The overall assessment results for play 6 are

shown in table 1. Oil and gas-condensate liquids form 45% of the hydrocarbon energy endowment of play 6. Table 5 reports the detailed assessment results by commodity for play 6.

Table 3 summarizes the volumetric input data developed for the GRASP computer model of North Aleutian basin play 6. Table 4 reports the risk model used for play 6. The location of play 6 is shown in figure 1.

The rocks comprising the Mesozoic Buried Granitic Hill play correspond to the Mesozoic plutonic complex exposed in the Alaska Range to the northeast of the North Aleutian basin. The latter rocks are the roots of a volcanic arc system of Jurassic and Cretaceous age. The volcanic arc system is long-lived and remains active today as the chain of large, active volcanoes along the backbone of the Alaska Peninsula.

Jurassic and Cretaceous plutonic rocks are overlain unconformably by Tertiary strata in wells in the northeastern parts of the North Aleutian basin. This plutonic complex was penetrated by 3 wells (Great Basins 1, Great Basins 2, and Becharof Lake 1 wells) at depths ranging from 8,780 to 10,860 feet. Plutonic rocks (quartz diorite) in the lowermost 15 ft of the Port Heiden 1 well have been variously assigned to the Middle Jurassic or the Eocene-Oligocene Meshik volcanics. Radiometric dating of some of these plutonic rocks by the K-Ar method have yielded ages of 96.3 Ma (Great Basins 2 well), 120 Ma, and 177 Ma (Great Basins 1 well), or, ranging from mid-Cretaceous to Middle Jurassic in equivalent stratigraphic

age.

No pools of oil or gas were encountered in any of the well penetrations of the Mesozoic magmatic arc complex. A gas seep at “Gas Rocks” along the southwest shore of Becharof Lake is located along the projected trace of the Bruin Bay fault. This gas seep consists mostly of carbon dioxide and nitrogen.

On the eastern Alaska Peninsula and western Alaska Range, the Bruin Bay fault forms the contact between a Mesozoic volcano-plutonic arc terrane on the north and a Mesozoic sedimentary basin on the south. The Bruin Bay fault is extrapolated offshore as the boundary between a northern area of high-frequency, high-amplitude magnetic anomalies and a southern area of low-frequency, low-amplitude magnetic anomalies. We speculate that the magnetic anomaly field north of the projected Bruin Bay fault corresponds to the volcano-plutonic arc terrane exposed north of the Bruin Bay fault onshore. These rocks were penetrated beneath Tertiary strata in three wells (Great Basins 1, Great Basins 2, and Becharof Lake 1 wells) in the northeast part of North Aleutian basin. The magnetic anomaly field south of the projected Bruin Bay fault represents an offshore extension of the deformed Mesozoic sedimentary rocks of the Alaska Peninsula, as demonstrated by well penetrations of Mesozoic rocks at several wells to the west in St. George basin and at the Cathedral River 1, David River 1/1A, and Hoodoo Lake 2 wells on the Alaska Peninsula. The area of play 6 corresponds to the area of the high-frequency, high-amplitude magnetic anomaly field north of the offshore extension of the Bruin Bay fault. This magnetic anomaly field is interpreted to mark a substrate of Mesozoic volcano-plutonic rocks that underlies the northern

ninety-two percent of the North Aleutian Basin OCS Planning Area.

The Mesozoic basement rocks penetrated at the Great Basins 1 well are described from cores as polymictic conglomerates passing downward into granitic gneiss (with large orthoclase porphyroblasts) and lamprophyre (rich in dark minerals and transitional to gabbros). The Great Basins 2 well penetrated diorite and granite, brecciated and seamed with calcite veins. The Mesozoic rocks penetrated at the Becharof Lake 1 well are described as metamorphic green schist, meta-gabbro, and meta-diorite, highly fractured and veined by feldspar and quartz.

All of the undiscovered potential oil and gas resources of play 6 are associated with hypothetical pools lodged in fractured “granitic” (here referring to any felsic pluton or massive felsic volcanic flow) rocks that core basement uplifts of Tertiary age. These granite-cored uplifts were repeatedly exposed to weathering and erosion through early Tertiary (perhaps also Late Cretaceous) time. We hypothesize that fractures in the granites provided avenues for deep invasion by meteoric waters during times of surface exposure. The meteoric waters may have enlarged fractures through dissolution and created a bulk porosity that was later occupied by petroleum (following deep reburial). In addition to an abundance of fractures, fractures must be lengthy and sufficiently diverse in orientations and depth of penetration in the granitic body to establish effective connectivity across pool areas of thousands of acres. The granite-cored basement uplifts were eventually (in Late Eocene time, approx. 40 Ma) sealed beneath a regional shale within the lower part of the Stepovak Formation. We hypothesize that gas and oil arising from Type III and coaly source rocks of Tertiary

age in deep areas of the North Aleutian basin that surround the basement uplifts migrated up the bounding faults and invaded the fractured and weathered granites at the crest of the basement uplifts.

Features similar to the North Aleutian basin buried hills form important exploration targets in the Bohai (North China) basin and offshore Vietnam. Buried hills form an important play concept for exploration of the Mesozoic assemblage in ultra-deep waters of the U.S. Gulf of Mexico. In the productive analog from Vietnam, the granitic rocks range in age from 97 to 178 Ma (mid-Cretaceous to Middle Jurassic) and feature bulk porosity values ranging from up to 25.0%. Effective porosity averages between 2.5% and 3.8% and is roughly distributed in halves as “fracture porosity” and as “caverns” or “microcaverns”, the latter the legacy of dissolution of fracture surfaces by both hydrothermal and meteoric fluids. Vietnam’s largest field (Bach Ho) is lodged in a fractured granitic reservoir and produces approximately 280,000 bbl/day. Paul Post (pers. comm., August 2003) of the Minerals Management Service has compiled data on the buried hill oil and gas fields of China and Vietnam. Pool volumes can exceed 1 billion barrels of oil and 2 trillions of cubic feet of gas. Productive columns can range up to 3,300 feet. Initial production rates can exceed 18,000 barrels of oil per day. Oil recovery factors can range up to 900 bbl/acre-foot (F50 = 158 bbl/acre-foot). The variability in these fractured reservoirs is such that the upper parts of the reservoir can be sparsely fractured while better fracture systems exist deeper in the buried hill. Many hydrocarbon accumulations in Vietnam and China (and elsewhere) may have been missed because exploration wells stopped drilling as soon as granitic rocks were encountered in the belief that it was economic basement and no

hydrocarbons could be housed there. The data compiled and analyzed by Paul Post for analog features in China and Vietnam formed the basis for the pay thickness and oil and gas yields used in the play 6 resource model (prospect areas are based on MMS seismic mapping).

Three major risk factors for play 6 relate to: **1) reservoir** (requires extensive fractures, enhanced by weathering, and of sufficient vertical and horizontal lengths and diversity of orientation to achieve connectivity across an area of tens of thousands of acres); **2) adequate source** (no attractive source formation in known Tertiary-age rocks); and **3) migration** (hydrocarbons generated in deep basin areas surrounding basement uplifts must first migrate vertically up bounding faults to reach the horsts, but then must encounter sealing levels on the same faults that act to divert hydrocarbons into the crests of uplifts; there is some risk that these faults will instead allow the hydrocarbons to escape upwards into overlying Tertiary sedimentary rocks).

A maximum of 15 hypothetical pools is forecast by the aggregation of the risk model and the prospect numbers model for play 6. These pools range in mean conditional (un-risked) recoverable volumes from 2 Mmboe (pool rank 15) to 148 Mmboe (pool rank 1). Pool rank 1 ranges in possible conditional recoverable volumes from 9 Mmboe (F95) to 469 Mmboe (F05), or, in the gas case, from 0.05 Tcfge (F95) to 2.64 Tcfge (F05). [Table 2](#) shows the conditional sizes of the 10 largest pools in play 6.

<b>Play 6, Mesozoic Buried Granitic Hills, North Aleutian Basin OCS Planning Area, 2006 Assessment, Conditional BOE Sizes of Ten Largest Pools</b>			
Assessment Results as of November 2005			
Pool Rank	BOE Resources *		
	F95	Mean	F05
1	9	148	469
2	3	42	131
3	1.6	21	64
4	1.1	13	40
5	0.8	9	28
6	0.64	7	21
7	0.54	6	16
8	0.47	4.7	13
9	0.40	4.0	11
10	0.35	3.5	10

\* Conditional, Technically-Recoverable, Millions of Barrels Energy-Equivalent (Mmboe), from "PSRK.out" file  
F95 = 95% chance that resources will equal or exceed the given quantity  
F05 = 5% chance that resources will equal or exceed the given quantity  
BOE = total hydrocarbon energy, expressed in barrels-of-oil-equivalent, where 1 barrel of oil = 5,620 cubic feet of natural gas

**Table 2**

In the computer simulation for play 6 a total of 13,089 “simulation pools” were sampled for size. These simulation pools can be grouped according to the USGS size class system in which sizes double with each successive class. Pool size class 10 contains the largest share (2,483, or 19%) of simulation pools “discovered” among the 10,000 trials conducted by the computer simulation for play 6. Pool size class 10 ranges from 16 to 32 Mmboe. The 4 largest simulation pools for play 6 fall within pool size class 18, which ranges in size from 4,096 to 8,192 Mmboe (23-46 Tcfge). [Table 6](#) reports statistics for the simulation pools developed in the GRASP computer model for play 6.

**GRASP Play Data Form (Minerals Management Service-Alaska Regional Office)**

Basin: North Aleutian Basin  
 Play Number: 6  
 Play UAI Number: AAAAA HAG

Assessor(s): K.W. Sherwood, D. Comer, J. Larson  
 Play Name: Mesozoic Buried Granitic Hills (Jurassic-Cretaceous Magmatic Rocks)  
 Date: December 2004

Play Area: 46,810 mi<sup>2</sup> (30 million acres)  
 Reservoir Thermal Maturity: Fractured Granite Reservoir  
 (0.34%-0.60% Ro projected from depth range)

Play Depth Range: 6,000-12,000 feet (mean = 9,000 ft)  
 Expected Oil Gravity: 35<sup>o</sup> API  
 Play Water Depth Range: 15-400 feet (mean = 300 ft)

**POOLS Module (Volumes of Pools, Acre-Feet)**

Fractile	F100	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Prospect Area (acres)-Model Input*	4000		5537		13119	16454/12456			31082				92660
Prospect Area (acres)-Model Output**	1281	4235	5538	8339	13240	16493/11905	21097	27029	31445	39296	46000	50000	90285
Fill Fraction (Fraction of Area Filled)	0.02	0.07	0.08	0.12	0.15	0.17/0.08	0.2	0.25	0.28	0.33	0.4	0.45	1
Productive Area of Pool (acres)	108	523	696	1157	2008	2838/2846	3473	4615	5690	7550	9600	12000	30768
Pay Thickness (feet)	88	115	142	184	254	276/116	351	405	435	505	547	561	575

\* model fit to prospect area data in *BESTFIT*  
 \*\* output from @RISK after aggregation with fill fraction

**MPRO Module (Numbers of Pools)**

Input Play Level Chance	0.35	Prospect Level Chance	0.117	Exploration Chance	0.04095
Output Play Level Chance*	0.3426				

\* First Occurrence of Non Zero Pools As Reported in PSUM Module

Risk Model	Play Chance	Petroleum System Factors	Prospect Chance
	0.35	Reservoir (granites fractured with weathering enhancement)	0.3
		Source (mainly Tertiary coals and Type III shales)	0.65
		Migration (fault migration paths must both transmit [deep] and seal [shallow])	0.6

Fractile	F99	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Numbers of Prospects in Play	24	26	27	29	32	31.99/3.62	33	34	36	38	40	42	48
Numbers of Pools in Play						1.31/2.10	3	4	5	6	7	8	15

Zero Pools at F34.28

Minimum Number of Pools	2 (F30)	Mean Number of Pools	1.31	Maximum Number of Pools	15
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**POOLS/PSRK/PSUM Modules (Play Resources)**

Fractile	F100	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Oil Recovery Factor (bbl/acre-foot)	5	31	43	81	158	228/191	310	444	580	610	680	710	1000
Gas Recovery Factor (Mcf/acre-foot)	3	27	38	73	146	218/193	290	420	541	620	695	730	1200
Gas Oil Ratio (Sol'n Gas)(cf/bbl)	56	162	195	267	376	426/220	531	638	723	871	1073	1100	1110
Condensate Yield (bbl/Mmcf)	1	14	17	21	25	25/7	29	32	34	35	37	39	50

Pool Size Distribution Statistics from *POOLS* (1,000 BOE):  $\mu$  (mu)= 9.814  $\sigma^2$  (sigma squared)= 2.170 Random Number Generator Seed= 599,626

BOE Conversion Factor (cf/bbl)	5620	Probability Any Pool Contains Both Oil and Free Gas (Gas Cap)	0.1
Probability Any Pool is 100% Oil	0.1	Fraction of Pool Volume Gas-Bearing in Oil Pools with Gas Cap	0.9
Probability Any Pool is 100% Gas	0.8		

Table 3. Input data for North Aleutian basin play 6, 2006 assessment.



**GRASP - Geologic and Economic Resource Assessment Model - PSUM Module Results**

Minerals Management Service - Alaska OCS Region  
 GRASP Model Version: 8.29.2005)  
 Computes the Geologic Resource Potential of the Play

**Play UAI: AAAAAHAG**      **Play No. 6**

World Level -      World Level Resources  
 Country Level -      UNITED STATES OF AMERICA  
 Region Level -      MMS - ALASKA REGION  
 Basin Level -      **NORTH ALEUTIAN BASIN**  
**Play Level -      Play 6 Mesozoic Basement-Buried Granitic Hills (Iliamna Terrane)**

Geologist Sherwood Comer Larson  
 Remarks 2005 Assessment  
 Run Date & Time: Date 19-Sep-05 Time 14:08:22

**Summary of Play Potential**

Product	MEAN	Standard Deviation
<b>BOE (Mboe)</b>	67,016	209,860
<b>Oil (Mbo)</b>	25,600	170,090
<b>Condensate (Mbc)</b>	4,841	11,142
<b>Free (Gas Cap &amp; Nonassociated) Gas (Mmcf)</b>	195,070	446,270
<b>Solution Gas (Mmcf)</b>	10,470	60,477

10000 (Number of Trials in Sample)  
 0.3426 (MPhc [Probability] of First Occurrence of Non-Zero Resource)  
 Windowing Feature: used

**Empirical Probability Distributions of the Products**

Greater Than Percentage	BOE (Mboe)	Oil (Mbo)	Condensate (Mbc)	Free (Gas Cap & Nonassociated) Gas (Mmcf)	Solution Gas (Mmcf)
100	0	0	0	0	0
99.99	0	0	0	0	0
99	0	0	0	0	0
95	0	0	0	0	0
90	0	0	0	0	0
85	0	0	0	0	0
80	0	0	0	0	0
75	0	0	0	0	0
70	0	0	0	0	0
65	0	0	0	0	0
60	0	0	0	0	0
55	0	0	0	0	0
50	0	0	0	0	0
45	0	0	0	0	0
40	0	0	0	0	0
35	0	0	0	0	0
30	27,164	2,252	3,038	121,960	973
25	60,396	5,772	6,573	267,620	2,425
20	96,037	16,262	9,431	387,800	7,535
15	141,980	35,155	12,819	514,630	13,649
10	207,720	45,269	19,950	782,150	18,734
8	244,390	65,115	21,278	859,480	28,455
6	295,250	77,087	24,734	1,053,500	33,573
5	330,010	92,683	29,339	1,128,200	40,704
4	373,570	148,740	25,376	1,055,200	65,668
2	535,220	205,240	38,587	1,550,400	87,215
1	778,890	481,900	31,407	1,266,200	226,380
0.1	2,090,100	1,837,800	14,834	552,870	781,650
0.01	7,583,800	7,257,600	6,544	276,550	1,520,100
0.001	7,645,600	7,352,500	1,704	62,374	1,575,100

**Table 5.** Assessment results by commodity for North Aleutian basin play 6, 2006 assessment.

Basin: NORTH ALEUTIAN BASIN Play 6 - Mesozoic Basement - Buried 'Granite Hills' UAI Key: AAAAAHAG				Model Simulation "Pools" Reported by "Fieldsize.out" GRASP Module																			
Classification and Size				Pool Count Statistics				Pool Types Count			Mixed Pool Range		Oil Pool Range		Gas Pool Range		Total Pool Range		Pool Resource Statistics (MMBOE)				
Class	Min (MMBOE)	Max (MMBOE)	Pool Count	Percentage	Trial Average	Trials w/Pool Avg	Mixed Pool	Oil Pool	Gas Pool	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Total Resource	Average Resource		
1	0.0312	0.0625	2	0.01528	0.0002	0.000584	0	0	2	0	0	0	0	1	1	1	1	1	1	0.044667	0.060378	0.105046	52.522812
2	0.0625	0.125	10	0.0764	0.001	0.002918	0	0	10	0	0	0	0	1	1	1	1	1	1	0.076139	0.122668	0.938182	93.818232
3	0.125	0.25	35	0.2674	0.0035	0.010213	0	0	35	0	0	0	0	1	1	1	1	1	1	0.133691	0.245400	6.955869	198.739126
4	0.25	0.5	102	0.77928	0.0102	0.029764	0	0	102	0	0	0	0	1	2	1	2	1	2	0.252775	0.498527	38.854707	380.928516
5	0.5	1	250	1.910001	0.025	0.07295	11	1	238	1	1	1	1	1	3	1	3	1	3	0.503408	0.997195	185.708240	742.832959
6	1	2	498	3.804722	0.0498	0.145317	12	3	483	1	1	1	1	1	4	1	4	1	4	1.000423	1.997302	757.837493	1.521762
7	2	4	1030	7.869203	0.103	0.300554	61	16	953	1	1	1	1	1	3	1	3	1	3	2.002297	3.995690	3063.352000	2.974128
8	4	8	1709	13.056766	0.1709	0.498687	146	44	1519	1	2	1	1	1	4	1	4	1	4	4.000048	7.999813	10020.001000	5.863078
9	8	16	2302	17.587288	0.2302	0.671725	233	88	1981	1	2	1	1	1	5	1	5	1	6	8.001881	15.999944	26934.493000	11.700475
10	16	32	2483	18.970127	0.2483	0.72454	271	149	2063	1	3	1	2	1	4	1	4	1	4	16.014612	31.995534	57191.594000	23.033264
11	32	64	2173	16.601727	0.2173	0.634082	297	238	1638	1	2	1	2	1	6	1	6	1	6	32.009933	63.971943	98253.850000	45.215763
12	64	128	1397	10.673084	0.1397	0.407645	167	260	970	1	2	1	2	1	3	1	4	1	4	64.047795	127.920870	124234.169000	88.929253
13	128	256	733	5.600122	0.0733	0.21389	74	249	410	1	2	1	2	1	3	1	3	1	3	128.045658	255.880717	128829.654000	175.756683
14	256	512	247	1.887081	0.0247	0.072075	13	144	90	1	1	1	3	1	2	1	3	1	3	256.264768	511.864226	87148.264000	352.826965
15	512	1024	86	0.65704	0.0086	0.025095	5	66	15	1	1	1	2	1	1	1	2	1	2	523.986899	1021.573000	63065.118000	733.315308
16	1024	2048	22	0.16808	0.0022	0.00642	0	19	3	0	0	1	1	1	1	1	2	1	2	1039.814000	2019.103000	32836.275000	1.492558
17	2048	4096	5	0.0382	0.0005	0.001459	0	5	0	0	0	1	1	0	0	1	1	1	1	2192.284000	3263.423000	12584.957000	2.516991
18	4096	8192	4	0.03056	0.0004	0.001167	0	4	0	0	0	1	1	0	0	1	1	1	1	4844.397000	7528.041000	25004.125000	6.251031
19	8192	16384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
20	16384	32768	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
21	32768	65536	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
22	65536	131072	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
23	131072	262144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
24	262144	524288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
25	524288	1048576	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000	0.000000	0.000000
Not Classified			1	0.00764	0.0001	0.000292	Below Class		0	0	1	Below Class		0.019493	0.019493	0.019493		19.492921					
Totals			13089	100.000008	1.3089	3.819376	Above Class		0	0	0	Above Class		0.000000	0.000000	0.000000		0.000000					

Number of Pools not Classified: 1	Min and Max refer to numbers of pools of the relevant size class that occur within any single trial in the simulation.	Min and Max refer to aggregate resources of the relevant size class that occur within any single trial in the simulation.
Number of Pools below Class 1: 1		
Number of Trials with Pools: 3427		

**Table 6.** Statistics for simulation pools created in computer sampling run for North Aleutian basin play 6, 2006 assessment.

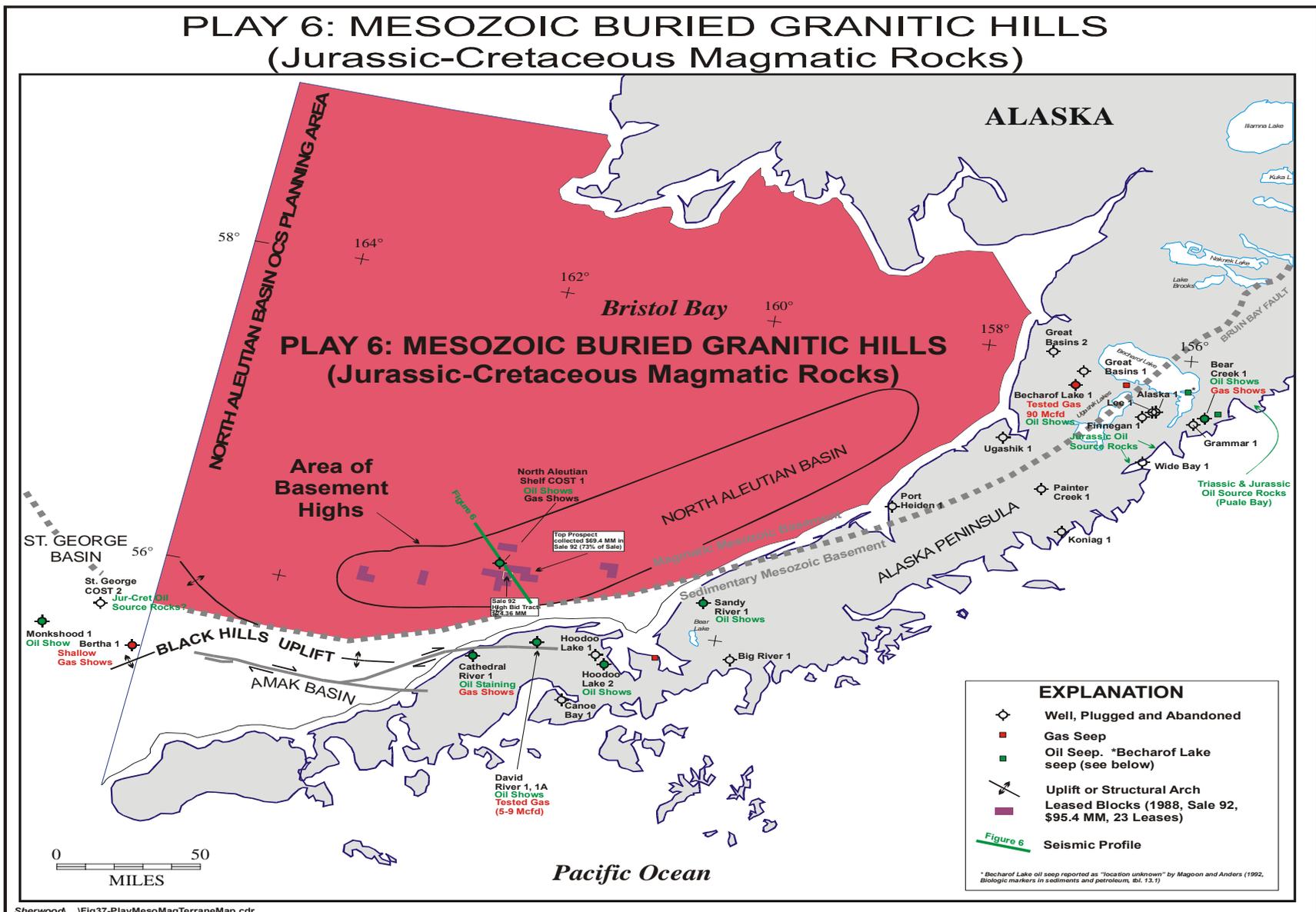


Figure 1. Map location of North Aleutian basin play 6, 2006 assessment.